Reactive Power Compensation of Unbalanced Spot Welding Loads

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Introduction

Reactive Power compensation and Harmonic mitigation works well when loads are balanced in a three phase network but unbalanced loads pose many issues and need compensation system designed exclusively for handling such loads. A group of 440 Volts single phase spot welding machines connected between phase to phase in a three phase network provide unbalanced load to the extent of more than 80% unbalance coupled with significant harmonic levels and complex harmonic spectrum. Though the machines are equally distributed in three phases yet the actual loading of three phases cannot be kept uniform due to random loading of machines and regularly varying number of occurrences of spotting operations on different phases which typically last 8 to 10 cycles each.

Nature of 440 Volts Single Phase Spot Welding Loads connected to three phase network

1. Non Linear

   Harmonics noted in a typical installation were

   Total current Harmonic Distortion 32 %, Third Harmonic 26%, 5th Harmonic 9%,

   7^{th} Harmonic 3%, 11^{th} Harmonic 2%, 13^{th} Harmonic 1%

2. Unbalanced

   The unbalance observed at the same location was to the extent of more than 80%.

   This is value prevalent in most installations.

3. Very small duration of load cycle

   Duration of one occurrence of spot welding operation is in the range of 8 to 10 cycles (160 milliseconds to 200 milliseconds)

4. Rapidly varying load

   The load keeps varying rapidly and continuously depending upon the number of machines in operation at a particular instant. The unbalance in different phases can be to the extent of 80% or more.

5. Very low Power Factor

   The Power Factor observed is in the range of 0.6 Lag in most installations.

Present status of compensation at various installations

Present status of Reactive compensation and Harmonic Mitigation for these installations varies from half solutions to no solutions. The reason for this state of affairs is emphasis on applying conventional solutions available for balanced

loads. Contactor switched systems when applied fail miserably compared to Real Time Thyristorised systems which work with limited success and with problems associated with over compensation and under compensation of phases at different instants. The ill effects of half solutions or no solutions are:

1. Unequal Voltage Drop in phases
2. Large Neutral Currents causing overloading of neutral conductors.
3. Under Utilization of Transformer Capacity.
4. Over voltage and over current in phases which are passing through over compensation.

   The permissible over compensation level is 15% but actual over compensation could go beyond 80%.
5. Risk of resonance due to indiscriminate application of compensation in different phases.

   This may lead to peak currents many times higher than the designed values of power and control components.
6. Frequent failure of Thyristors and Thyristor control cards.

Failure to run spot welding loads on DG supply

Spot welding loads are most often kept off during outages of grid power supply as because

small capacity stand by DG sets are not able to accept these heavily unbalanced and rapidly varying loads. This causes production loss during outages of utility power.

Workable Solution – Individual Phase Compensation Schemes

A workable solution needs to have following features:

1. Real Time Based
2. Compensation to each phase independently as per the load on the phase
3. Harmonic Filtration

There are different capacitor configurations to achieve the objective. The scheme is simple if applied with star connected earthed neutral but precautions have to be taken for strengthening of neutral which carries the unbalance current in addition to the filtered Harmonic content. Star connected floating neutral scheme and Delta connected scheme do not pose neutral strengthening issue but the design matrix is complex and needs experienced handling.

Thyristor Switching Modules (TSM)

The major problem encountered by applying conventional balanced compensation RTPFC system for unbalanced fast changing cyclic loads such as spot welding loads is frequent failures of Thyristors and Thyristor Control Cards. Individual phase compensation scheme significantly reduces chances of TSM failures. Despite all precautions, occurrence of resonance cannot be completely ruled out in today's hostile harmonic environment. The TSM cards thus need to have extra safety features to prevent their failures.

Some important safety features needed to be incorporated in TSM modules for such critical applications are:

- ❖ Isolation of Thyristor in case of current spikes due to external load conditions
- ❖ Isolation of Thyristor in case of High Over Current caused by Resonance conditions
- ❖ Isolation of Thyristor in case of Under Current caused by heavy de-rating of capacitors. This is important to avoid unbalanced compensation in different phases and also to avoid unintended compensation values being applied.

General considerations to eliminate TSM failures

- ❖ Adequately designed Heat sinks
- ❖ Proper isolation between control and power circuits
- ❖ Correct sensing of voltage zero across Thyristors in Harmonics environment
- ❖ Right selection of PIV rating and auxiliary supply voltage

Other Special Features recommended for Individual Phase Compensation Scheme are:

- Use of Single phase Capacitors
- Load on each phase independently sensed and corresponding compensation applied independently for each phase.
- The unbalance level of compensation in different phases kept below 15%
- Tuned Filters
- Optimum design to avoid occurrence of Resonance at critical harmonic frequencies
- Real Time cycle to cycle correction to match load variations in each phase

Conclusion

The unbalanced spot welding loads remain normally uncompensated as the conventional balanced load compensation systems do not work satisfactorily. The result is very poor power factor, higher operating currents, Higher KVA Demand, High losses, under utilization of transformer capacity, poor voltage profile, poor quality of weld and high rejections etc. The stand by Diesel Generators are not able to support this load resulting in production loss in the event of utility power outage. The individual phase compensation scheme is recommended to meet unequal reactive power needs of different phases.